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Title: Measurement cell development for the neutron EDM experiment

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Measurement cell development for the neutron EDM experiment

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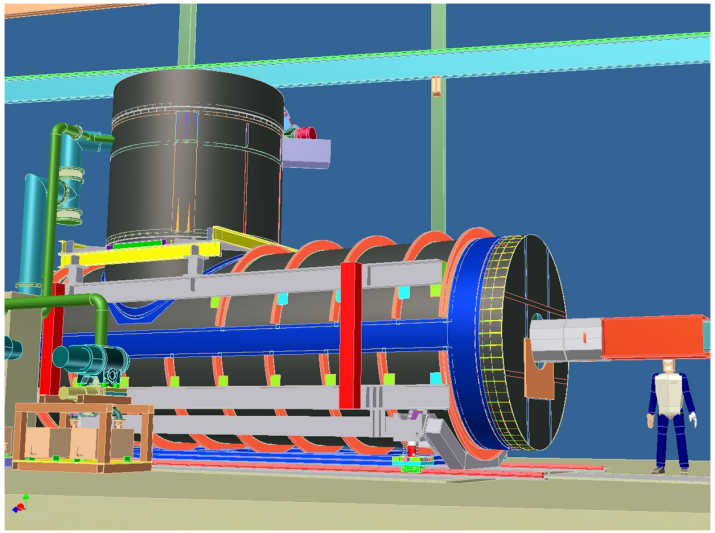
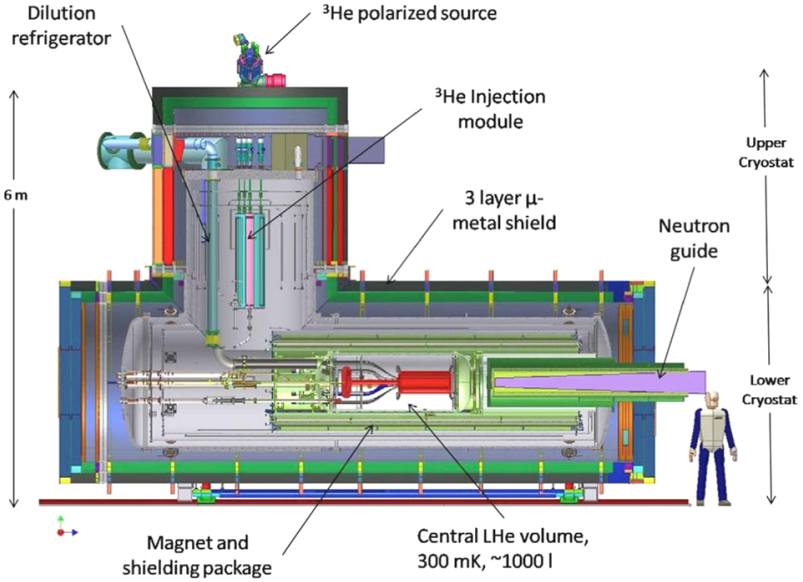
nEDM Collaboration

2012 DNP meeting, Newport Beach CA

Neutron EDM search

- a finite permanent electric dipole moment of the neutron = new ~~CP~~ physics
- current limit: $|d_n| < 3.0 \times 10^{-26}$ e cm C.A. Baker et al, PRL 97, 131801 (2006).
  - stored UCNs + ^{199}Hg comagnetometer
- SNS neutron EDM experiment: improve limit by 2 orders of magnitude
  - generate UCNs in superfluid ^{4}He
  - polarized ^{3}He acts as comagnetometer and n spin analyzer





nEDM cells

- nEDM cells are planned to be constructed from acrylic, coated with deuterated-polystyrene (dPS) + deuterated-TPB
- It is crucial that the cell has a long ^{3}He polarization lifetime (verified to be ~ 25000 s for dPS+dTPB), long UCN storage time, and that the cell walls act as efficient light guides
- UCN storage time in a bottle:

$$\frac{1}{\tau} = \frac{1}{\tau_n} + \frac{1}{\tau_{wall}(v)} + \frac{1}{\tau_{hole}(v)} + \frac{1}{\tau_{tunnel}(v)} + \frac{1}{\tau_{He3}} + \ldots$$

  - hole loss: $1/\tau_{hole} = v A_h / 4V_b$

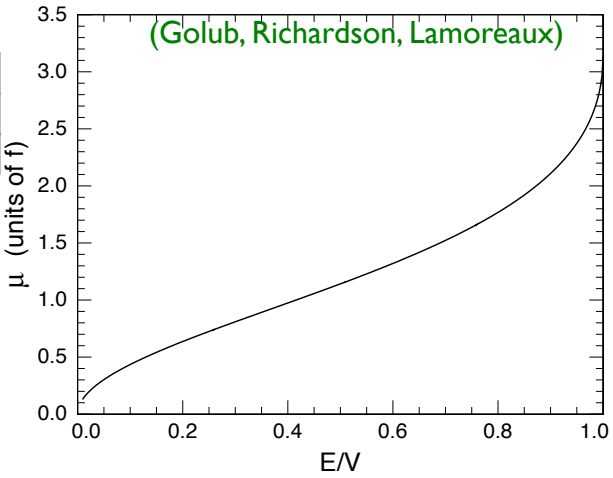
    for hole loss time ~ 2000 sec in a 3 L bottle, need holes/gaps to controlled to ~ 1.5 mm^2

  - wall loss: $\frac{1}{\tau_{wall}} = \frac{v\bar{\mu}}{\lambda}$ $\quad \bar{\mu}(E) = 2f\left[\frac{V}{E}\sin^{-1}\left(\frac{E}{V}\right)^{1/2} - \left(\frac{V}{E} - 1\right)^{1/2}\right]$

    $\bar{\mu}$ = average UCN loss probability per bounce

    λ = mean free path = 8 cm, V=160 neV for dPS

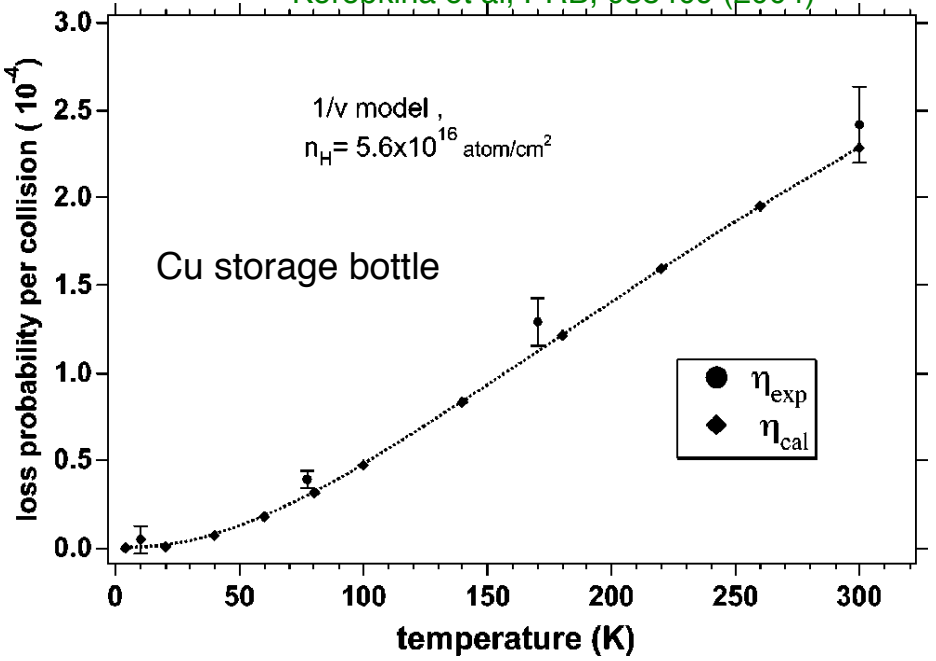
    f is a material dependent "wall loss factor"



Wall loss factor

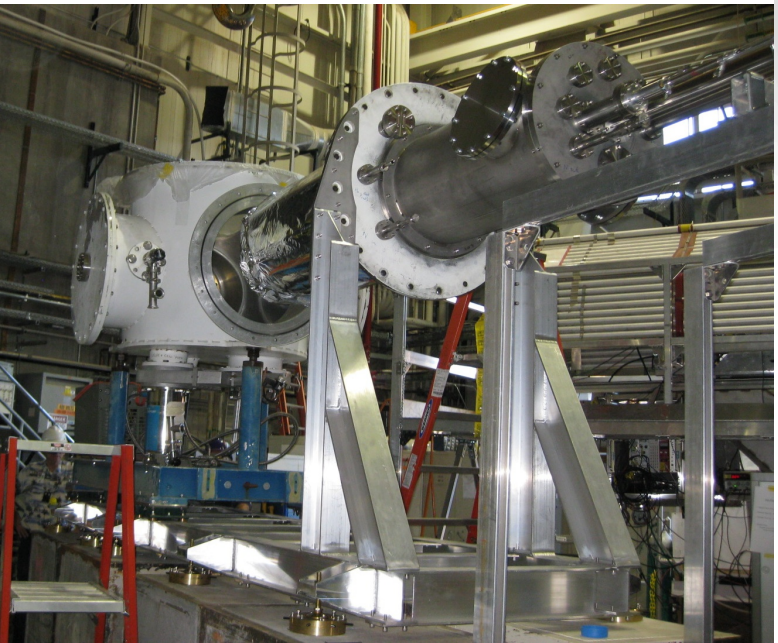
- Ideally, want $f \sim 10^{-5}$
- room temperature f are typically $> 10^{-4}$ due to H upscattering
  - reduced by going to low temperature
  - nEDM experiment will operate below 1 K

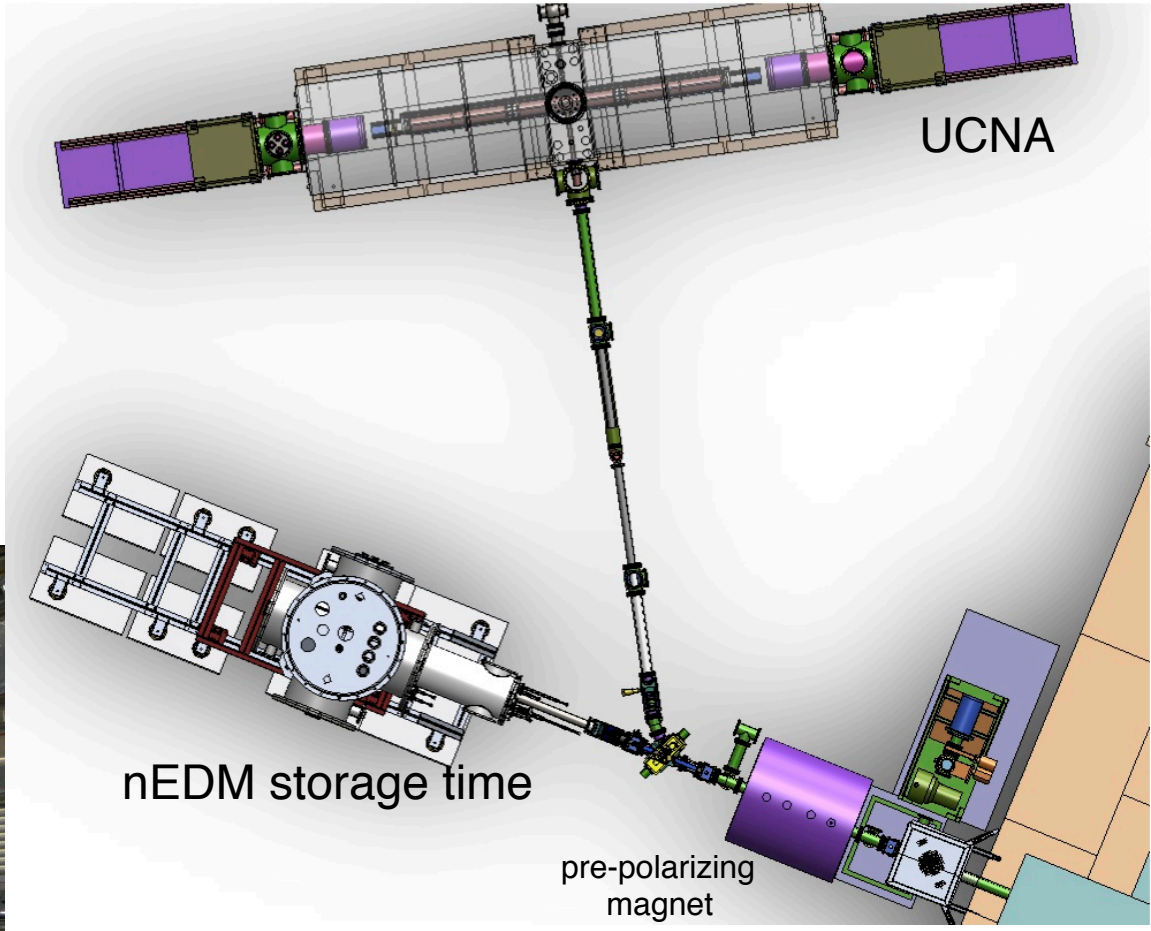
Korobkina et al, PRB, 035409 (2004)



LANL UCN storage time tests

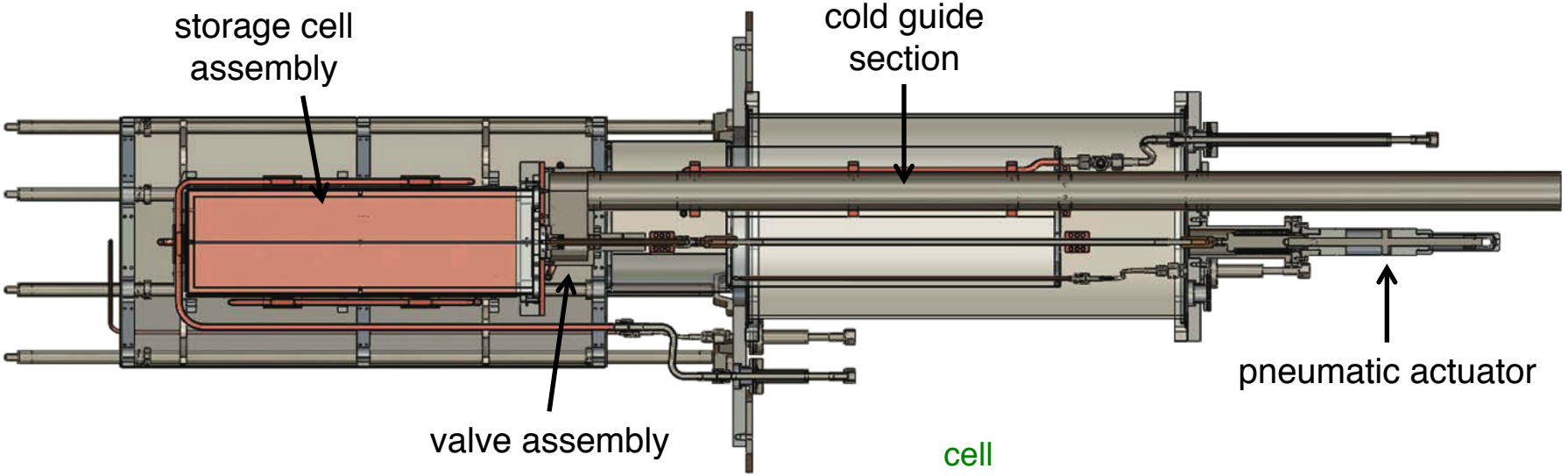
- utilizes currently operating LANSCE UCN source
- test wall coatings and cell construction for UCN storage
- cells will eventually be tested for 3He+UCN performance at NCSU/ PULSTAR

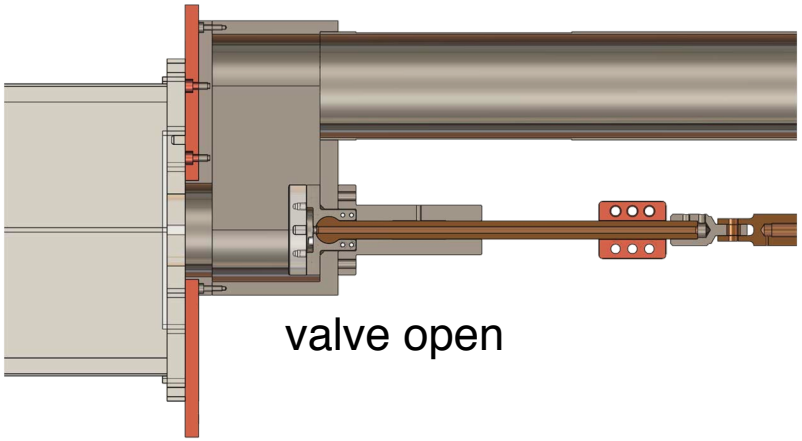


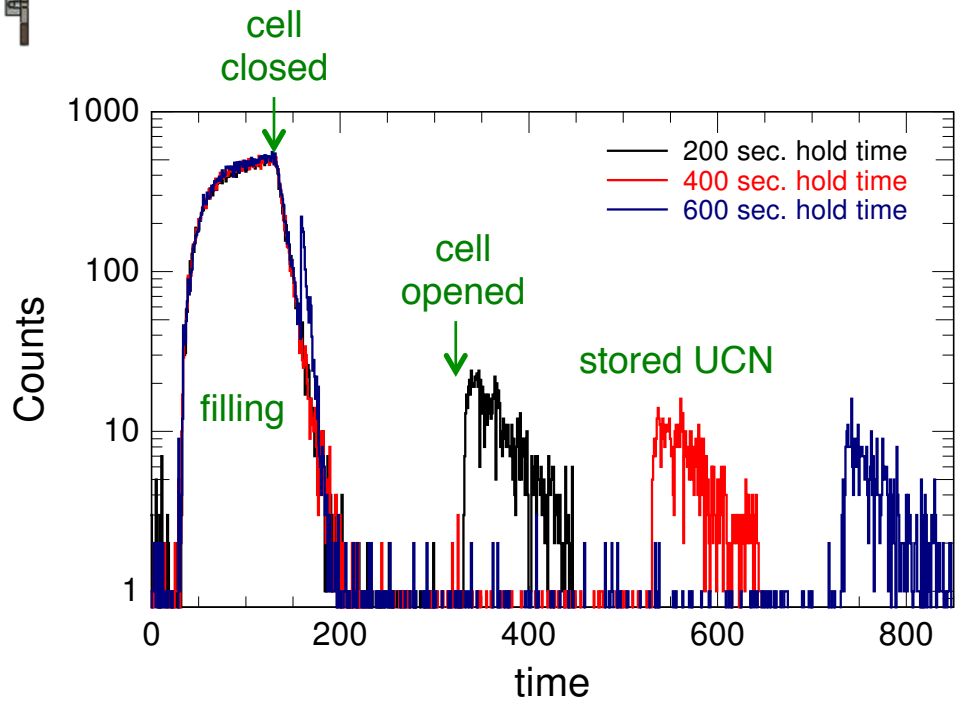


SD_2 UCN source

Storage time measurement apparatus

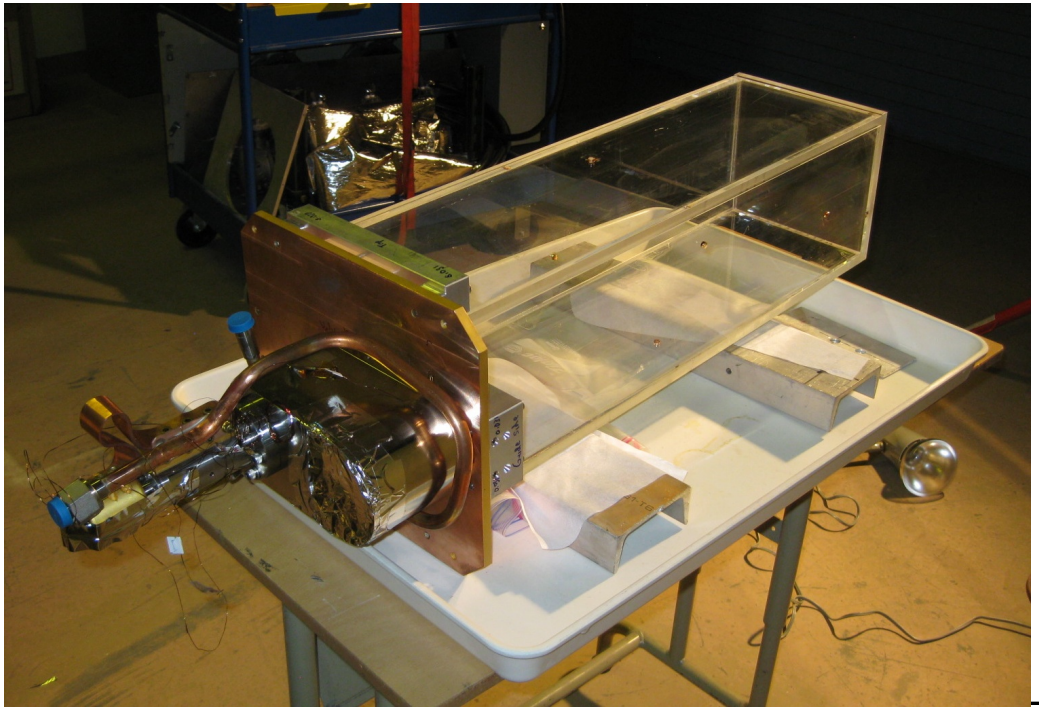




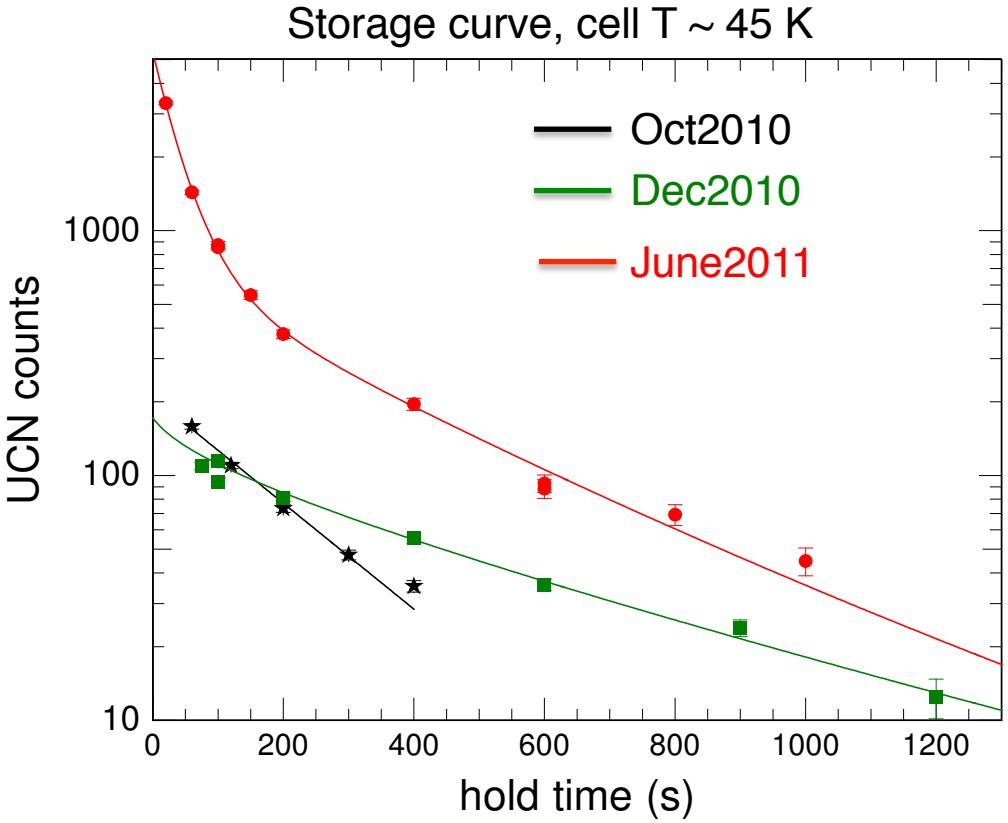


20 L test cells

- started with 8x8x26”, 20 L volume test cells
  - nEDM cells planned to be 3 L, 7.5x10x40 cm
  - larger cell makes any valve gap losses less important
- uncoated acrylic plates were first glued together, then slosh coated with dPS in d-toluene
- 3 cells were built and tested with UCN
  - Oct 2010, Dec 2010, June 2011



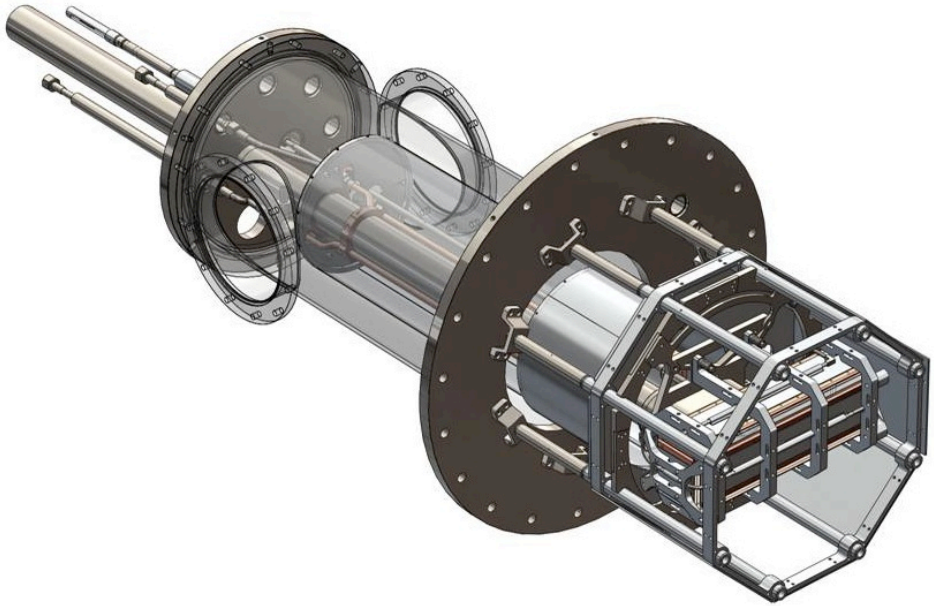
20L cell data

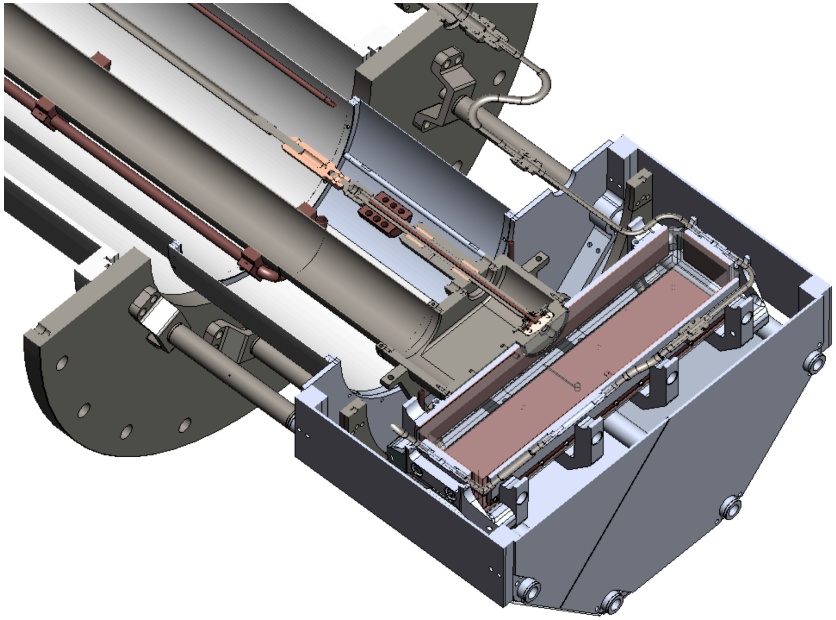


- Oct 2010 cell had long (>24 hour) exposure to d-toluene during coating, probably dissolved acrylic into wall coating
- Dec 2010 cell had thin areas of dPS coating that could have given tunneling losses
- June 2011 cell possibly had a small patch with a lower potential

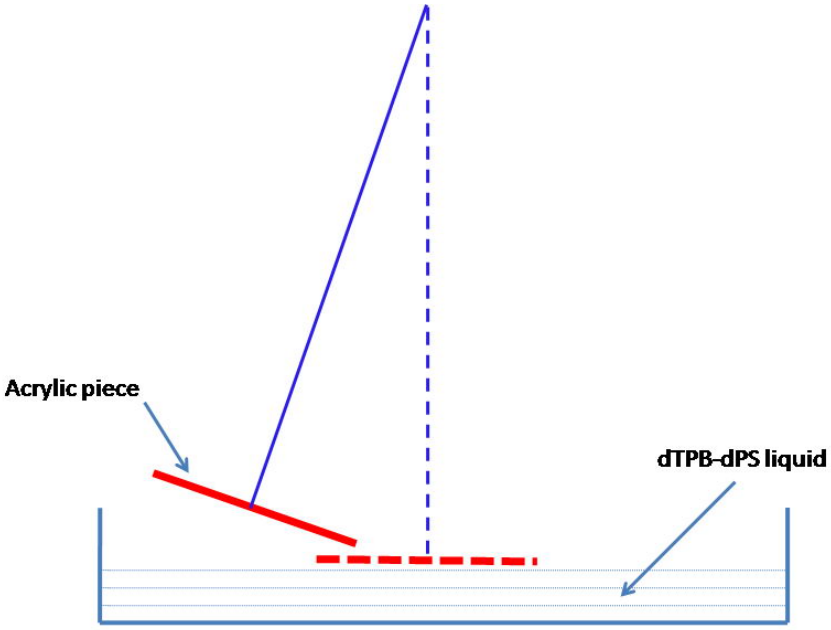
Transition to 3L nEDM-sized cells

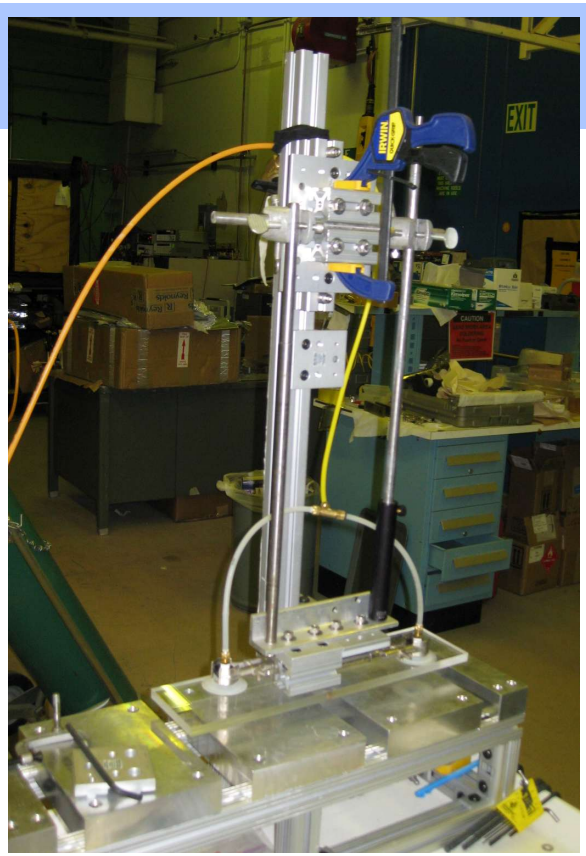
- 3” x 4” x 40 cm, 1cm diam. entrance hole in middle of a long face – same dimensions as eventual nEDM cells
- demonstrated < 0.001” valve gap in 20L cells
  - 0.001” valve gap would give 4000 s hole loss time in 3L cell
- dPS+dTPB coating, applied with “swing” method



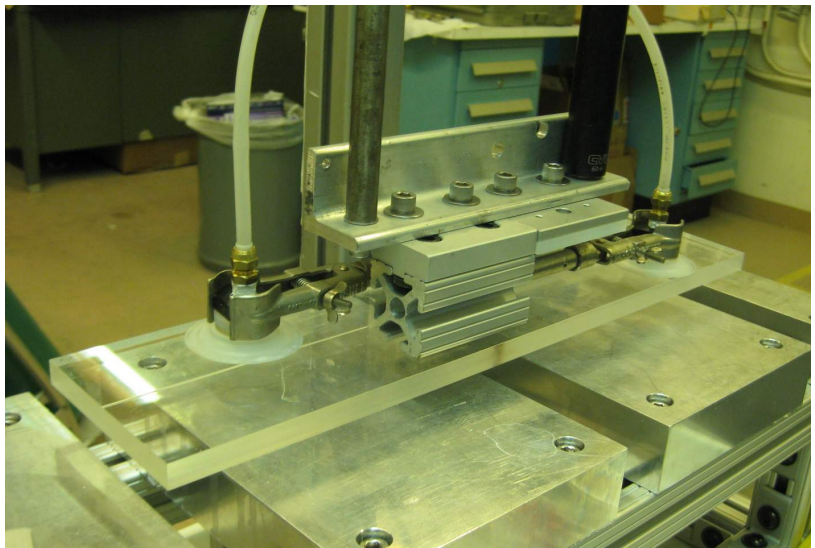


Swing coating

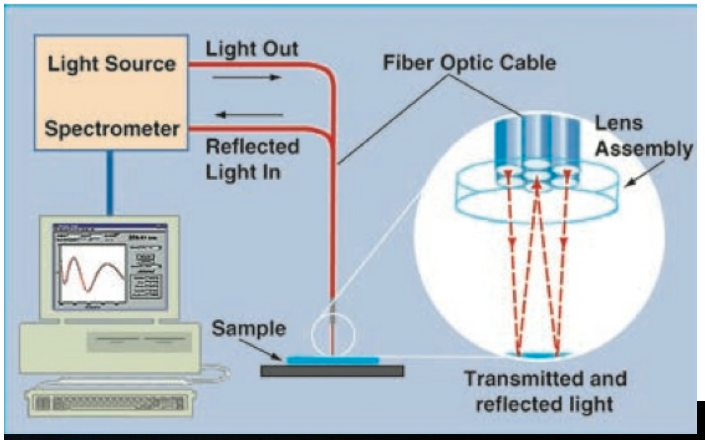


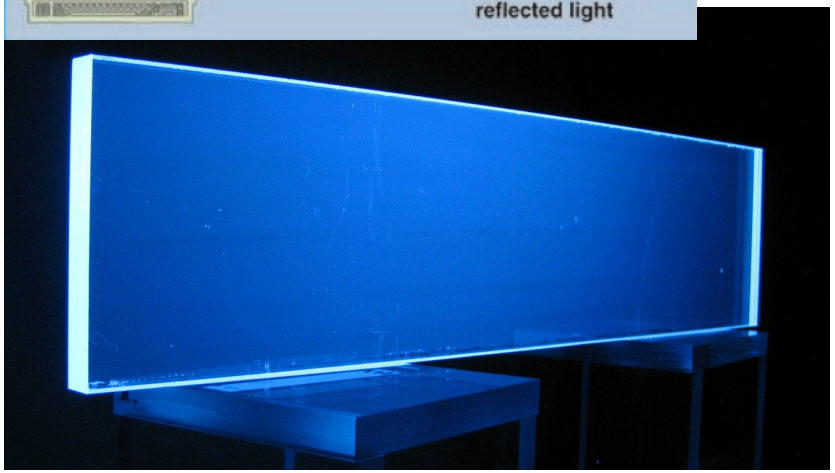


- technique developed during ^{3}He wall depolarization studies (Gao, Golub, Ye)
- plate is dipped into d-toluene +dPS/dTPB solution, swung out very slowly and smoothly

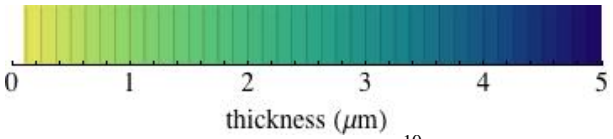


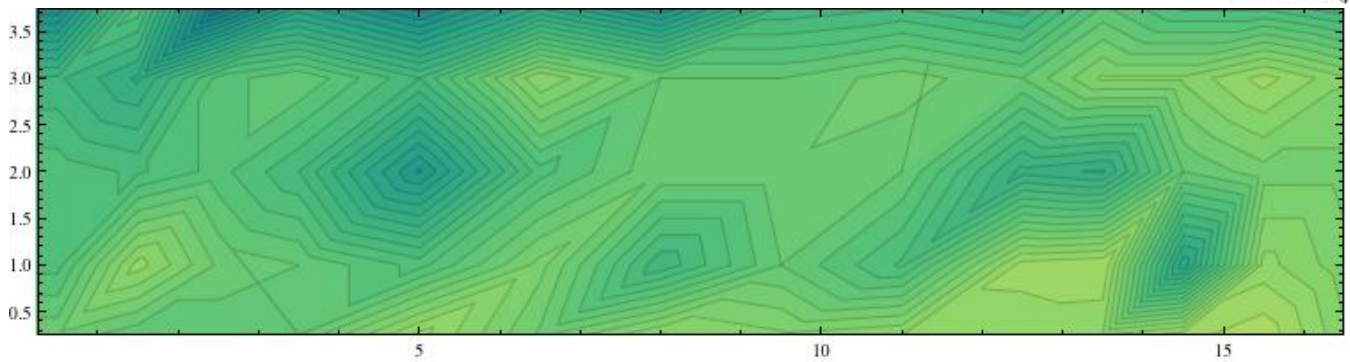
Coating thickness

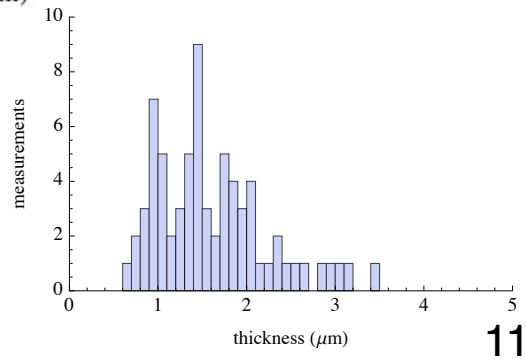




- coating thickness is checked with a spectral reflectometer
- thickness > 100 nm to avoid tunneling losses
- 1-2 microns is adequate for light production
- have seen crazing after temperature cycling when > 4 microns





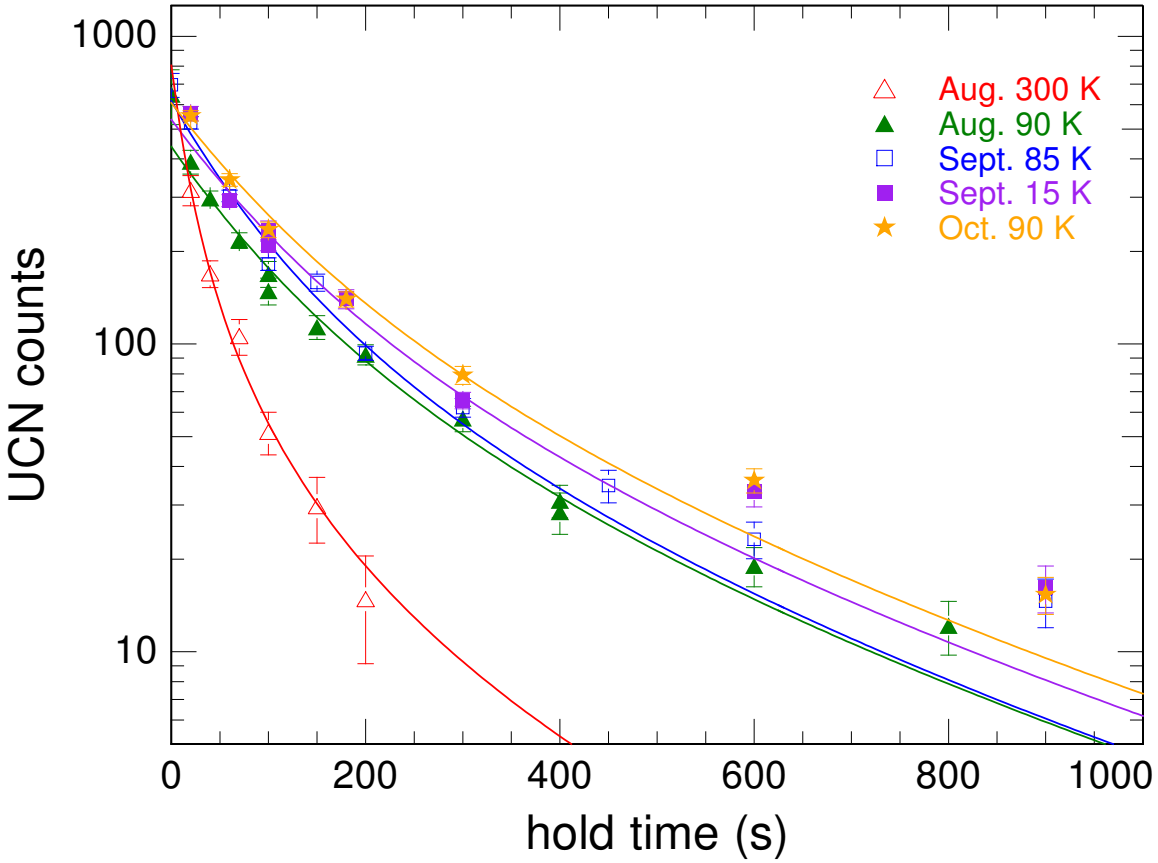


Cell gluing

- glue: deuterated MC-Bond
  - methylene chloride (81%), methyl methacrylate (14%), acetic acid (5%)
- joints are optically clear, mostly bubble-free, have survived multiple cryogenic cycles without cracking

First 3L cell data

- 3L test cell coated with dPS+dTPB, glued with deuterated-MCbond, UCN data from Aug.19-23, Sept. 11-13, and Oct. 5 (2012)

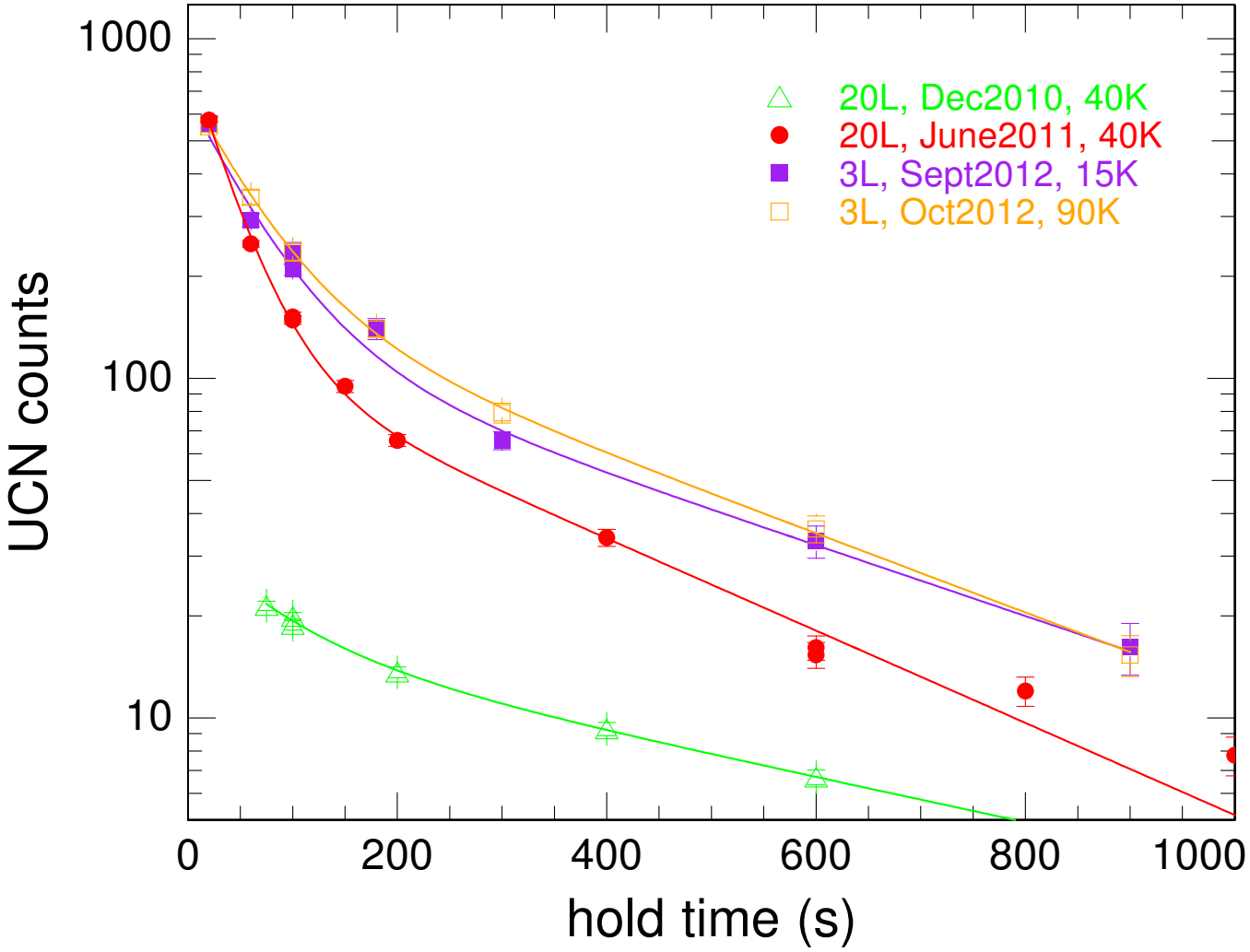


- velocity dependent wall loss fit indicates avg. loss per bounce of:
  7×10^{-3} at room temp.
  1×10^{-4} at 15-90 K
  (goal is ~ 10^{-5})

- between Sept. and Oct. baked cell at 50 C for 2 weeks, purged with Ar gas several times
  - reduced cell outgassing by 10x, possibly gave a small improvement in storage

Comparison to 20 L data

- 20 L data volume scaled by 3/20, all curves normalized to 150 gate valve cts/sec (open)



Summary

- making progress on cell construction strategy for nEDM
- wall loss values from fit depend on understanding the UCN velocity spectrum
  - divergence at longer storage times indicates an issue with the v-spectrum, or a different loss mechanism:
    - could have a 0.001” gap along a glue joint with potential < 100 neV
    - also investigating vibrations, surface roughness issues…
- suspect issue with glue joints
  - some small gaps/bubbles were visible along inside edges
  - covered over these edges with a bead of coating liquid inserted with a syringe
  - may help to do additional overcoating along the glued edges